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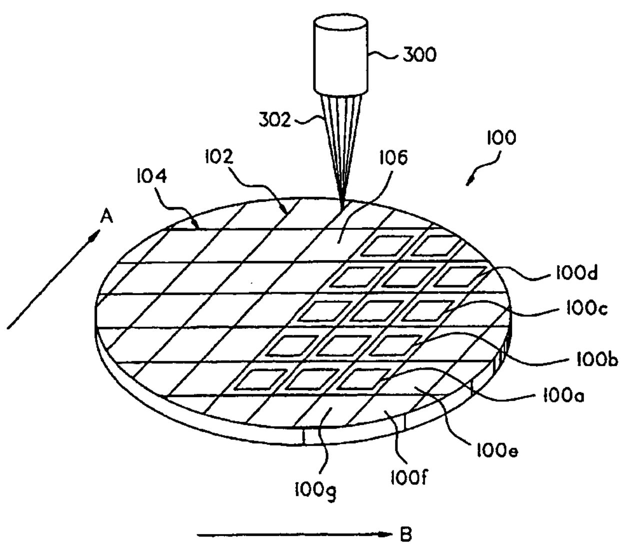
(54) Title: A METHOD FOR DICING WAFERS WITH LASER SCRIBING



(57) Abstract: A method for laser scribing and mechanically dicing a substrate. The method comprises the steps of focusing a laser beam on a top surface of the substrate; forming a first set of scribe lines in a first direction on the substrate by scanning the laser beam across the surface of the substrate; forming a second set of scribe lines in a second direction on the surface of the substrate substantially orthogonal to the first set of scribe lines; and dicing the substrate along the first set and second set of scribe lines to form a plurality of dice.

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A METHOD FOR DICING WAFERS WITH LASER SCRIBING

FIELD OF THE INVENTION

This invention relates generally to dicing of semiconductor wafers. More specifically, the present invention relates to a method for laser scribing semiconductor wafers prior to mechanical dicing of the semiconductor wafer.

BACKGROUND OF THE INVENTION

Die separation, or dicing, by sawing is the process of cutting a microelectronic substrate into its individual circuit die with a rotating circular abrasive saw blade. This process has proven to be the most efficient and economical method in use today. It provides versatility in selection of depth and width (kerf) of cut, as well as selection of surface finish, and can be used to saw either partially or completely through a wafer or substrate.

Wafer dicing technology has progressed rapidly, and dicing is now a mandatory procedure in most front-end semiconductor packaging operations. It is used extensively for separation of die on silicon integrated circuit wafers.

Increasing use of microelectronic technology in microwave and hybrid circuits, memories, computers, defense and medical electronics has created an array of new and difficult problems for the industry. More expensive and exotic materials, such as sapphire, garnet, alumina, ceramic, glass, quartz, ferrite, and other hard, brittle substrates, are being used. They are often combined to produce multiple layers of dissimilar materials, thus adding further to the dicing problems. The high cost of these substrates, together with the value of the circuits fabricated on them, makes it difficult to accept anything less than high yield at the die-separation phase.

Dicing is the mechanical process of machining with abrasive particles. It is assumed that this process mechanism is similar to creep grinding. As such, a similarity may be found in material removal behavior between dicing and grinding. The size of the dicing blades used for die separation, however, makes the process unique. Typically, the blade thickness ranges from 0.6 mils to 50 mils (0.015 mm to 1.27 mm), and diamond particles (the hardest known material) are used as the abrasive material ingredient. Because of the

diamond dicing blade's extreme fineness, compliance with a strict set of parameters is imperative, and even the slightest deviation from the norm could result in complete failure.

FIG. 1 is an isometric view of a semiconductor wafer 100 during the fabrication of semiconductor devices. A conventional semiconductor wafer 100 may have a plurality of chips, or dies, 100a, 100b, . . . formed on its top surface. In order to separate the chips 100a, 100b, . . . from one another and the wafer 100, a series of orthogonal lines or "streets" 102, 104 are cut into the wafer 100. This process is also known as dicing the wafer.

Dicing saw blades are made in the form of an annular disc that is either clamped between the flanges of a hub or built on a hub that accurately positions the thin flexible saw blade.

Today's high end IC wafers are usually coated with a passivation layer of oxide or nitride that is further covered with a protective layer of polymer (collectively shown as 106 in Fig. 1). This combination of materials has a significant effect on wafer dicing and die edge quality. As shown in FIG. 4, when conventional dicing technology is used, such as single blade and single cut, the die edge on the bottom side of semiconductor wafer 400 suffers severe backside chipping (BSC) 406. In addition, on the topside of the wafer 400, problems at the die edge include cracking of the passive layer (not shown) and the formation of polymer slivers (not shown).

One approach to overcome the aforementioned die edge problems is a mechanical dual dicing method. This method is a combination of two cuts, the first one is shallow and the second one is a through cut. The first cut is usually performed with a beveled blade and the second with a standard blade. The purpose of the first cut is to remove the polymer coating and passivation layer 106 from the streets 102, 104 of semiconductor wafer 100 in order to permit a smooth through cut. The removal of the coating and passivation 106 from the streets 102, 104 also effects the backside chipping. As a result, the size of chipping is reduced somewhat. There are two disadvantages, however, to the beveled cut. First, when the blade wears out, the kerf gets wider and this requires frequent handling and replacement of the blade. In addition, the mechanical removal of the passive layer causes residual cracks, which causes further deterioration of the dice.

There are other disadvantages to the beveled cut. Namely, blade penetration height must be carefully monitored, because for each one micron of penetration, the kerf widens by about two microns. In addition, the beveled blade may insert hidden damage into the die edge, in the form of cracks for example. Visual inspection of dice after dicing (an industry standard) is not capable of detecting this damage. Furthermore, the beveled blade wears out rapidly and needs frequent replacement, which is a costly procedure.

In view of the shortcomings of the prior art, there is a need to develop a method to cut die having a passivation layer so as to minimize the back side chipping and increase the yield of useable circuits.

SUMMARY OF THE INVENTION

In view of the shortcomings of the prior art, it is an object of the present invention to optimize the dicing process and minimize bottom side chipping (BSC) of semiconductor wafers.

The present invention is a method for dicing a semiconductor substrate by focusing a laser beam on a top surface of the substrate; forming scribe lines on the substrate by scanning the laser beam across the surface of the substrate; and dicing the substrate along the scribe lines to form a plurality of dice.

According to another aspect of the invention, the substrate is diced with a dicing saw after the substrate is scribed.

According to still another aspect of the invention, the depth of the scribe line is between about 0.001 in. (0.025 mm) and 0.002 in. (0.050 mm).

These and other aspects of the invention are set forth below with reference to the drawings and the description of exemplary embodiments of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention is best understood from the following detailed description when read in connection with the accompanying drawing. It is emphasized that, according to common practice, the various features of the drawing are not to scale. On the contrary, the dimensions of the various features are arbitrarily expanded or reduced for clarity. Included in the drawing are the following Figures:

Fig. 1 is an isometric view of a semiconductor wafer used to form semiconductor devices;

Fig. 2 is a flow chart of an exemplary method of the present invention;

Fig. 3 is a diagram of an exemplary embodiment of the present invention;

Fig. 4 is an illustration of backside chipping of a substrate after dicing using conventional single blade techniques;

Fig. 5 is an illustration of backside chipping of a substrate after dicing according to a first exemplary embodiment of the present invention;

Fig. 6 is another illustration of backside chipping of a substrate after dicing according to an exemplary embodiment of the present invention;

Fig. 7 is an illustration of backside chipping of an untreated substrate after dicing;

Fig. 8 is another illustration of backside chipping of an untreated substrate after dicing;

Fig. 9 is an illustration of backside chipping of a substrate after dicing according to a further exemplary embodiment of the present invention; and

Fig. 10 is an illustration of backside chipping of a substrate after dicing according to yet another exemplary embodiment of the present invention.

DETAILED DESCRIPTION

In the manufacture of semiconductor devices, individual chips are cut from a large wafer using a very high speed rotating saw blade. In essence, the saw blade grinds away a portion of the wafer along linear streets or kerfs (102, 104 as shown in Fig.1) in one direction followed by a second operation in an orthogonal direction.

The quality of the dice (chips) is directly related to the minimization of chipping during the dicing operation. The inventors have determined that removing the passivation layer from the substrate in the area where the substrate will be cut through using a non-mechanical approach minimizes the BSC and increases the device yield.

Referring to Fig. 2, a flow chart of an exemplary embodiment of the present invention is shown. Referring to Fig. 3, the exemplary laser scribing principle is shown.

In Fig. 2, at Step 200, the laser beam 302 from laser 300 (shown in FIG. 3) is focused on the surface of the substrate 100. It should be noted that the laser beam 302 may also be focused at a point above or below the surface of substrate 100. At Step 205, the laser beam 302 is scanned across the surface of passivation layer 106 to remove passivation layer 106 and form desired scribe lines 102. The depth of the scribe line may be between about 0.001 in. (0.025 mm) and 0.002 in. (0.050 mm).

In the exemplary embodiment, the laser beam 302 is about 50μm in diameter, although other diameters may be used as necessary. In forming streets 102, 104 it may desirable that the laser beam 302 penetrate only the passivation layer and not impinge upon the surface of substrate 100. Alternatively, the laser beam 302 may be used to remove the polymer coating, such as a polyimide, and passivation layer from the street 102, 104 prior to dicing.

In the exemplary embodiment, the laser 300 is stationary while the substrate 100 is moved in direction A, for example, using a conventional X-Y table (not shown) onto which the substrate 100 is mounted, to form streets 102. As each street 102 is complete, substrate 100 is translated in direction B by the X-Y table and the process is repeated for an additional street 102.

After all of the streets 102 are formed, the substrate 100 is rotated by about 90° so that the process may be repeated to form streets 104 in substrate 100. Alternatively, the laser 300 may be moved relative to a stationary substrate 100 in either or both the X and Y directions.

At Step 210, the substrate is diced using conventional methods, such as a dicing saw, along the streets 102, 104 to form dies 100a, 100b, etc.

One advantage of laser scribing is that laser scribing may be performed at a much higher feed rate than the conventional bevel cut dicing process to remove the passivation layer. It should be noted, however, that the feed rates of the abrasive dicing which follows the laser scribing and the scribing are not necessarily the same.

Other advantages of the laser scribing over the bevel cut are 1) eliminating the need for expensive blades, and 2) allowing the possibility of sealing the passivation layer, thereby avoiding crack formation.

In a first exemplary method a wafer (substrate) was treated with a CO_2 laser beam for removal of the coating from the streets of the wafer prior to cutting, in order to decrease BSC. The wafer was treated with a uniform level of energy to remove the polyimide coating. All the streets 102, 104 were treated according to the same parameters. The parameters of the CO_2 laser were as follows:

Power = 15 Watts.

Speed = ~2"/sec (~51 mm/sec)

Following laser scribing, the wafer was diced on a conventional dicing apparatus using the following parameters:

Feed rate: 2"/sec (50.8 mm/sec),

Spindle speed: 30,000 rpm,

Blade type: 1235-010,

water flow: main 1.5 L/min,

cleaning 1 L/min,

spray bar 1 L/min,

The wafer was subjected to microscopic analysis to determine the amount of BSC resulting from the dicing operation. FIG. 5 is a magnified view 500 of the BSC result where the polyimide layer is removed from the street according to the first exemplary embodiment before dicing the substrate. As shown in FIG. 5, the maximum BSC 502 is about 60 μm and the average BSC 504 is about 22 μm.

By contrast, FIG. 4 is a magnified view 400 of the BSC result where the polyimide was not removed before dicing the substrate. As shown in FIG. 4, the maximum BSC 402 is about 165 µm and the average BSC 404 is about 100 µm.

In a second exemplary embodiment, two wafers were mounted on NITTO tape. Only one of the wafers was treated by the CO_2 laser beam to remove the coating from the streets of the wafer prior to cutting. The wafer was treated with a uniform level of energy to remove the polyimide coating. Each wafer street was treated according to the same parameters.

The parameters of the CO_2 laser were as follows:

Power = 15 Watts

Feed rate = 2.5"/sec (63.5 mm/sec)

Following laser scribing, the wafer was diced on a conventional dicing apparatus using the following parameters:

rate: 2"/sec (50.8 mm/sec),

Spindle speed: 30,000 rpm,

Blade type: 1235-010,

water flow: main 1.5 L/min,

cleaning 1 L/min,

spray bar 1 L/min,

Although specific spindle speeds are illustrated, it is contemplated that the spindle speed may be at least 2,000 RPM and may be as high as 60,000 RPM. Furthermore, instead of a CO2 laser, other types of lasers may be used, such as a YAG laser or an Excimer laser. Use of different lasers may produce varying degrees of BSC improvement.

The laser is used primarily to remove various surface coatings, without damaging the edges of the scribe line. The improved BSC results from the removal of the coating.

The wafer was subjected to microscopic analysis to determine the amount of BSC resulting from the dicing operation.

Table I illustrates the BSC chipping results of the above test:

Channel		1	1	1	1		2	2	2	2		Total
Line #		1	2	3	4	AVG.	5	6	7	8	AVG.	average
Coating treated by laser scribing	Mean Max	29 69	19 41	17 37	11 34	**19** **45**	30 59	18 42	24 47	25 57	**24** **51**	**21.5** **48**
Coating not treated by laser scribing	Mean Max	67 170	79 178	64 134	80 205	**73** **172**	45 156	44 143	40 119	43 116	**43** **134**	**58** **153**

TABLE I

As shown in Table I, and illustrated in FIGS. 6 and 7, the removal of the polyimide coating by the CO_2 laser improves the BSC results, from 153μm max (702 in FIG. 7) and 58 μm average (704 in FIG. 7) BSC to 48 μm max (602 in FIG. 6) and 21.5 μm average (604 in FIG. 6).

In an further test, seven wafers were mounted on NITTO tape and treated with the CO_2 laser beam. The 7 wafers were divided to 3 groups, two groups of 3 wafers each, were used to compare between two levels of laser beam energy, and one group of 1 wafer, was used as a reference for standard dicing. The wafers were treated with a uniform level of energy to remove the polyimide coating as above.

The wafer streets were first treated with a CO_2 laser according to the following parameters:

Group #1	Group #2
Power = 10 Watts.	Power = 15 Watts.
Feed rate = 13"/sec (330.2mm/sec)	Feed rate = 13"/sec (330.2mm/sec)

Following the laser treatment, all of the wafers were then diced (through cut) on a conventional dicing machine using the following parameters:

Feed rate: 2.5""/sec (63.5 mm/sec),

Spindle speed: 30,000 rpm,

Blade type: Disco - NBC-ZH205F-SE.

water flow: main 1.5 L/min,

cleaning 1 L/min,

spray bar 1 L/min,

The wafer was subjected to microscopic analysis to determine the amount of BSC resulting from the dicing operation.

Table II illustrates the BSC chipping results of the above test:

Test #	Line #	Reference		Laser treated 10[w]		Laser treated 15[w]	
		max	Avg.	Max	Avg.	max	Avg.
1	1	116	52	77	35	43	25
1	2	59	45	50	29	65	27
1	3	116	56	65	34	53	35
1	4	92	52	54	32	56	37
1	5	106	50	52	27	82	45
mean per wafer:		97.8	51	59.6	31.4	59.8	33.8
2	1			39	23	88	41
2	2			60	30	60	31
2	3			57	37	42	20
2	4			47	29	60	45
2	5			54	38	52	34
mean per wafer:				51.4	31.4	60.4	34.2
3	1			39	21	60	25
3	2			50	27	57	37
3	3			56	31	60	33
3	4			75	45	52	32
3	5			52	31	49	27
mean per wafer:				54.4	31	55.6	30.8
Mean:		97.8	51	55.1	31.2	58.6	32.9
standard deviation:		23.8	4	10.9	6	12.5	7.4

TABLE II

As shown in Table II and illustrated in FIGS. 8-10, the BSC results on the two wafer groups that were treated by the CO_2 laser beam are low compared to the results on the non treated wafer (the reference wafer). FIG. 8 is a bottom view 800 of the reference wafer. FIG. 9 is the bottom view 900 of the wafer treated with a 10 Watt laser and FIG. 10 is the bottom view 1000 of the wafer treated with a 15 Watt laser.

As shown in FIG. 8, the BSC is 97.8 μm max (802 in FIG. 8) and 51μm average (804 in FIG. 8). As shown in FIG. 9, using a 10 Watt CO_2 laser to remove the polyimide coating improves the BSC results to 55.1 μm max (902 in FIG. 9) and 31.2 μm average (904 in FIG. 9). Furthermore, as shown in FIG. 10, using a 15 Watt CO_2 laser to remove the polyimide coating improves the BSC results to 58.6 μm max (1002 in FIG. 9) and 32.9 μm average (1004 in FIG. 10). On one hand, the results are repeatable in these

experiments, as seen from the standard deviation calculated for each group, but on the other hand the results are not equal to the results obtained by using of the same parameters in the second experiment.

Overall, the BSC improvement achieved using the exemplary embodiment is between approximately 40% and 70% over the results achieved using single blade conventional methods.

Although lasers with specific power rating are illustrated above, it is contemplated that lower or higher powered lasers may be used as desired. For example, it is contemplated that lasers having power rating as low as 2 Watts may be used to achieve reduced BSC.

Furthermore, rather that scribing the entire surface of the substrate before sawing, it is contemplated that as each scribe line is formed a dicing saw may be used to saw along that scribe line. Subsequent scribe lines may then be formed and sawed in sequence in the first direction across the surface of the substrate followed by a similar procedure along the second direction of the substrate to form the dice.

Although the invention has been described with reference to exemplary embodiments, it is not limited thereto. Rather, the appended claims should be construed to include other variants and embodiments of the invention which may be made by those skilled in the art without departing from the true spirit and scope of the present invention.

What is Claimed:

1. A method for dicing a semiconductor substrate comprising the steps of:

(a) aiming a laser beam on a top surface of the substrate;

(b) forming at first set of scribe lines in a first direction on the substrate by scanning the laser beam across the surface of the substrate, the laser beam partially penetrating the surface of the substrate, each one of said first set of scribe lines substantially parallel to one another;

(c) forming a second set of scribe lines in a second direction on the surface of the substrate, the second direction substantially orthogonal to the first direction, the laser beam partially penetrating the surface of the substrate, each one of said second set of scribe lines substantially parallel to one another; and

(d) dicing the substrate along the first set and second set of scribe lines to form a plurality of dice.

2. The method according to claim 1, further comprising the step of coating the substrate with a surface coating prior to step (a).

3. The method according to claim 2, wherein the coating is a polymer.

4. The method according to claim 1, wherein the coating is a polyimide.

5. The method according to claim 1, wherein the depth of the scribe lines is between about 0.001 in. (0.025 mm) and 0.002 in. (0.050 mm).

6. The method according to claim 1, wherein the scanning rate of the laser beam is between about 2.0 in/sec (50.8 mm/sec) and 25 in/sec (330.2 mm/sec).

7. The method according to claim 1, wherein the scanning rate of the laser beam is between about 2.0 in/sec (50.8 mm/sec) and 3.0 in/sec (76.2 mm/sec).

8. The method according to claim 1, wherein said step (d) further comprises the steps of:

(d1) sawing the substrate along the first set of scribe lines with a dicing saw rotating at a predetermined rate;

(d2) sawing the substrate along the second set of scribe lines with the dicing saw rotating at the predetermined rate.

9. The method according to claim 8, wherein the speed of the spindle is at least 2,000 rpm.

10. The method according to claim 8, wherein the speed of the spindle is between about 10,000 rpm and 57,000 rpm.

11. The method according to claim 1, wherein the laser beam is formed by an eximer laser.

12. The method according to claim 1, wherein the laser beam is formed by a CO2 laser.

13. The method according to claim 1, wherein the laser beam is formed by a YAG laser.

14. The method according to claim 1, wherein the laser beam has a power of between about 2 Watts and 15 Watts.

15. The method according to claim 1, wherein the laser beam has a power of about 15 Watts.

16. The device according to claim 1, wherein the laser beam has a cross sectional diameter of between about 25 μm and 100 μm.

17. The device according to claim 1, wherein the laser beam has a cross sectional diameter of about 50 μm.

18. The method according to claim 2, wherein the laser beam only penetrates the coating of the substrate.

19. The method according to claim 18, wherein the substrate is silicon and the coating of the substrate includes all layer other than silicon.

20. A method for dicing a semiconductor substrate using a laser and a dicing saw, the method comprising the steps of:

(a) aiming the laser beam on a top surface of the substrate;

(b) forming at first set of scribe lines in a first direction on the substrate by scanning the laser beam across the surface of the substrate, the laser beam partially penetrating the surface of the substrate, each one of said first set of scribe lines substantially parallel to one another;

(c) forming a second set of scribe lines in a second direction on the surface of the substrate, the second direction substantially orthogonal to the first direction, the laser beam partially penetrating the surface of the substrate, each one of said second set of scribe lines substantially parallel to one another; and

(d) cutting a first set of kerfs in the substrate with the dicing saw along the first set of scribe lines;

(e) cutting a second set of kerfs in the substrate with the dicing saw along the second set of scribe lines, wherein said first set of kerfs and said second set of kerfs form a plurality of dice from the substrate.

21. A method for dicing a semiconductor substrate using a laser and a dicing saw, the method comprising the steps of:

(a) aiming the laser beam on a top surface of the substrate;

(b) forming at first scribe line in a first direction on the substrate by scanning the laser beam across the surface of the substrate, the laser beam partially penetrating the surface of the substrate,

(c) cutting a first kerf in the substrate with the dicing saw along the first scribe line;

(d) forming a further first scribe line in the first direction on the substrate, the further scribe line substantially parallel to the first scribe line;

(e) cutting a further first kerf in the substrate with the dicing saw along the further first scribe line;

(f) repeating steps (d) and (e) in the first direction until the entire substrate is scribed and cut;

(g) forming a second scribe line in a second direction on the surface of the substrate, the second direction substantially orthogonal to the first direction, the laser beam partially penetrating the surface of the substrate,

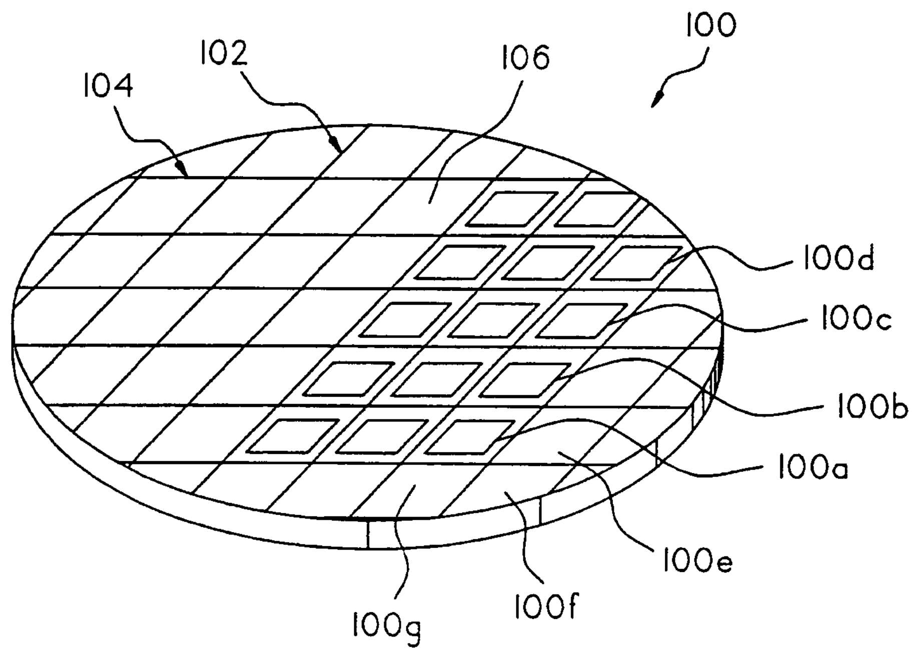
(h) cutting a second kerf in the substrate with the dicing saw along the second scribe line,

(i) forming a further second scribe line in the second direction on the substrate, the further second scribe line substantially parallel to the second scribe line;

(j) cutting a further second kerf in the substrate with the dicing saw along the further second scribe line; and

(k) repeating steps (i) and (j) in the second direction until the entire substrate is scribed and cut;

wherein the first kerf, the further first kerfs, the second kerf and the further second kerfs form a plurality of dice from the substrate.



(Prior Art)

FIG. 1

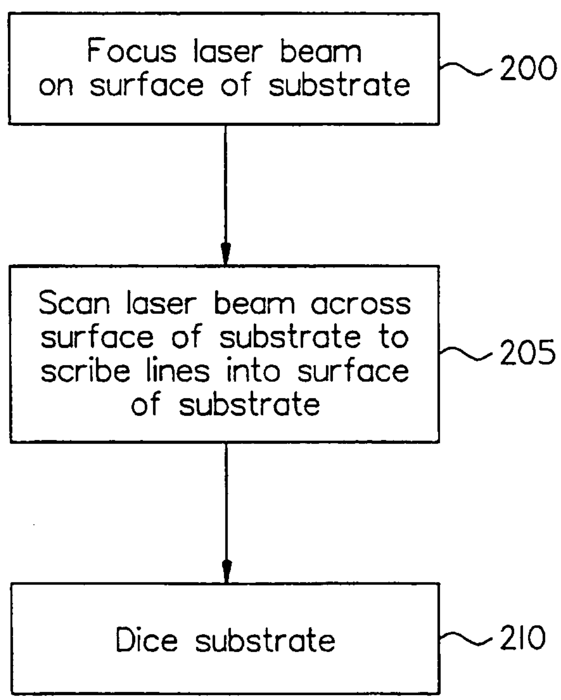

Focus laser beam on surface of substrate
200
Scan laser beam across surface of substrate to scribe lines into surface of substrate
205
Dice substrate
210

FIG. 2

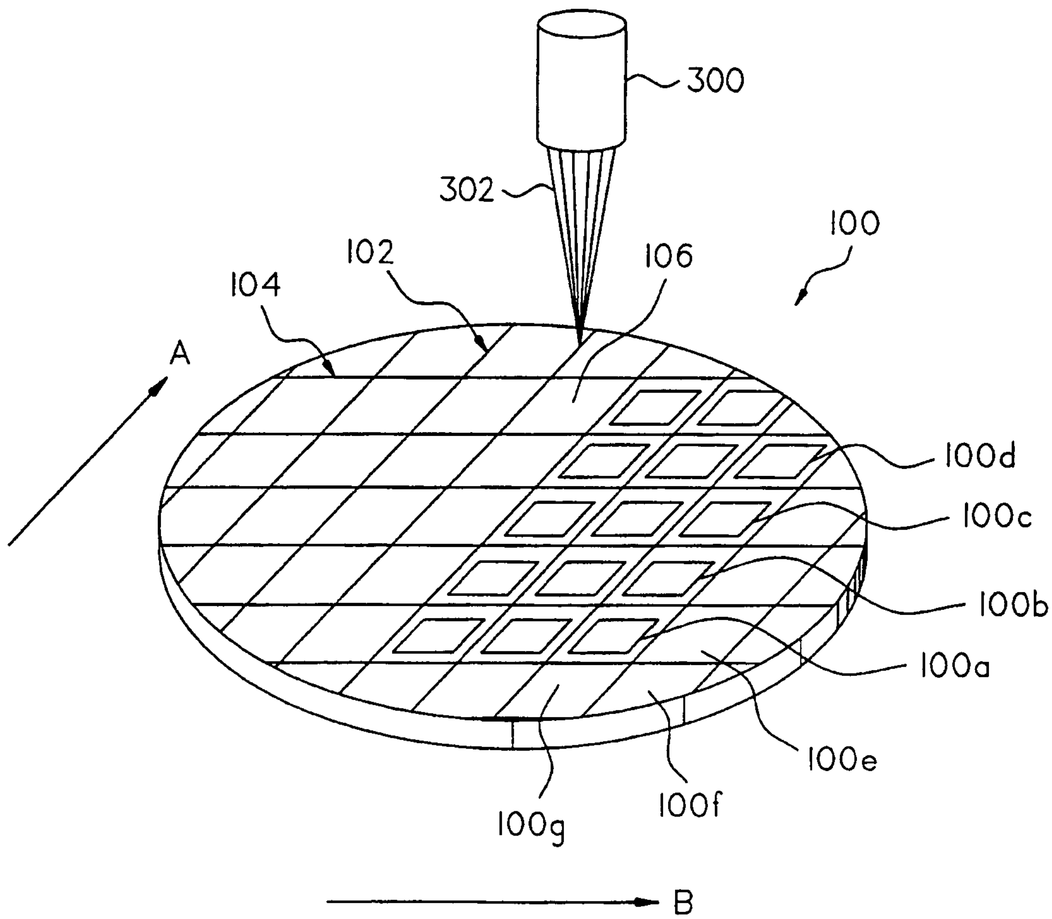
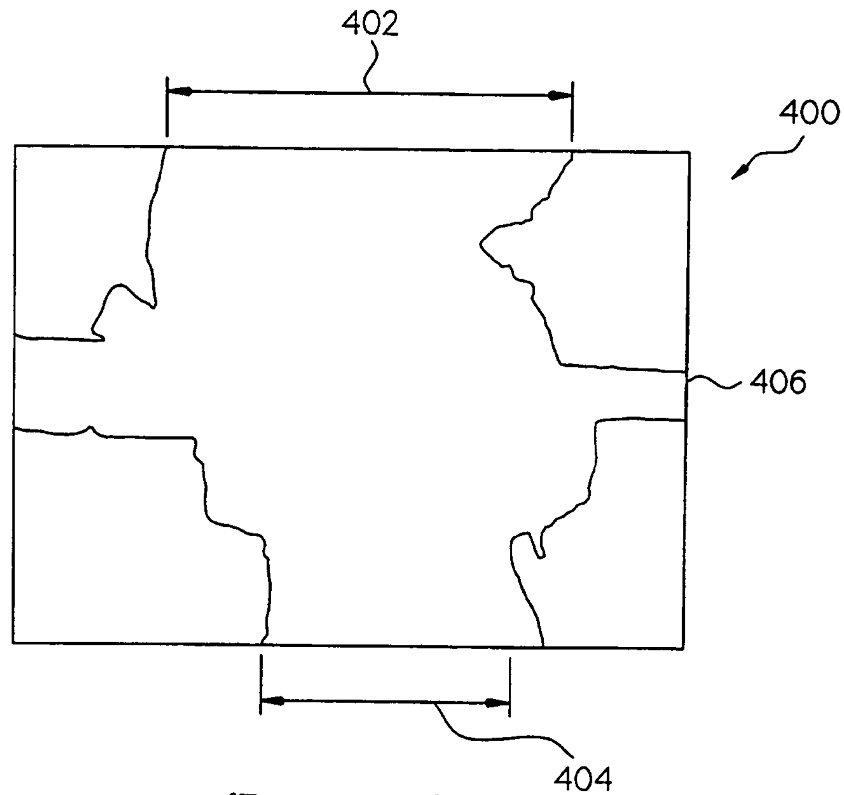


FIG. 3



(Prior Art)
FIG. 4

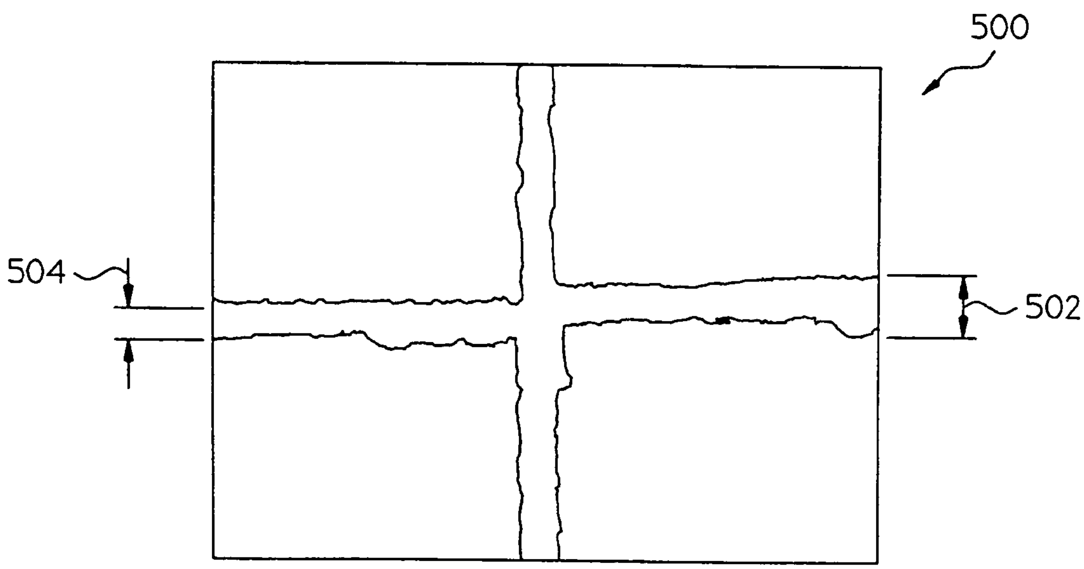


FIG. 5

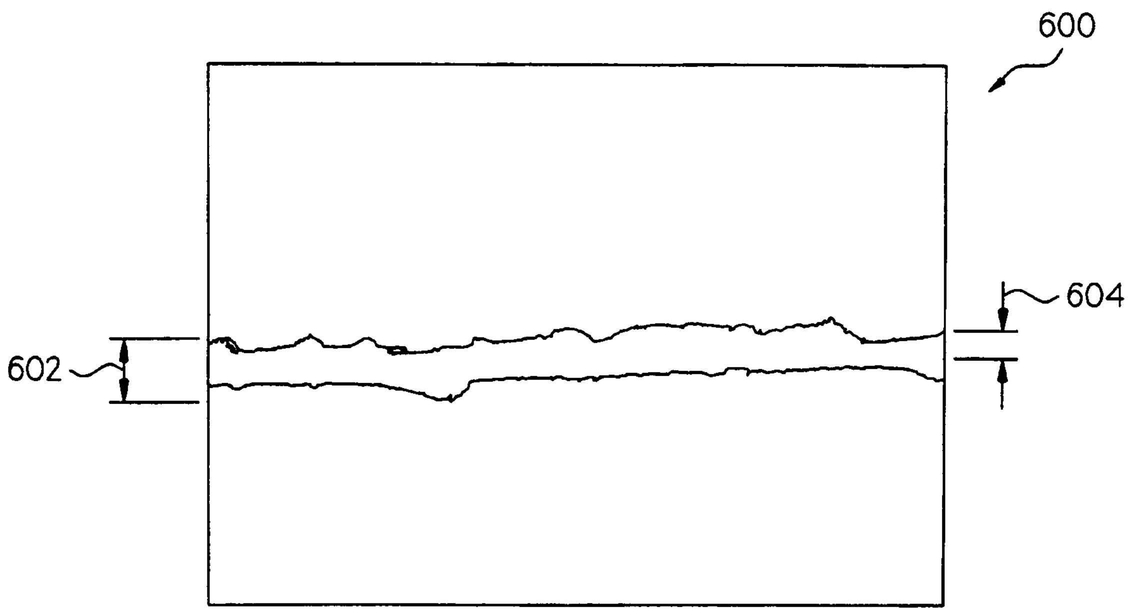


FIG. 6

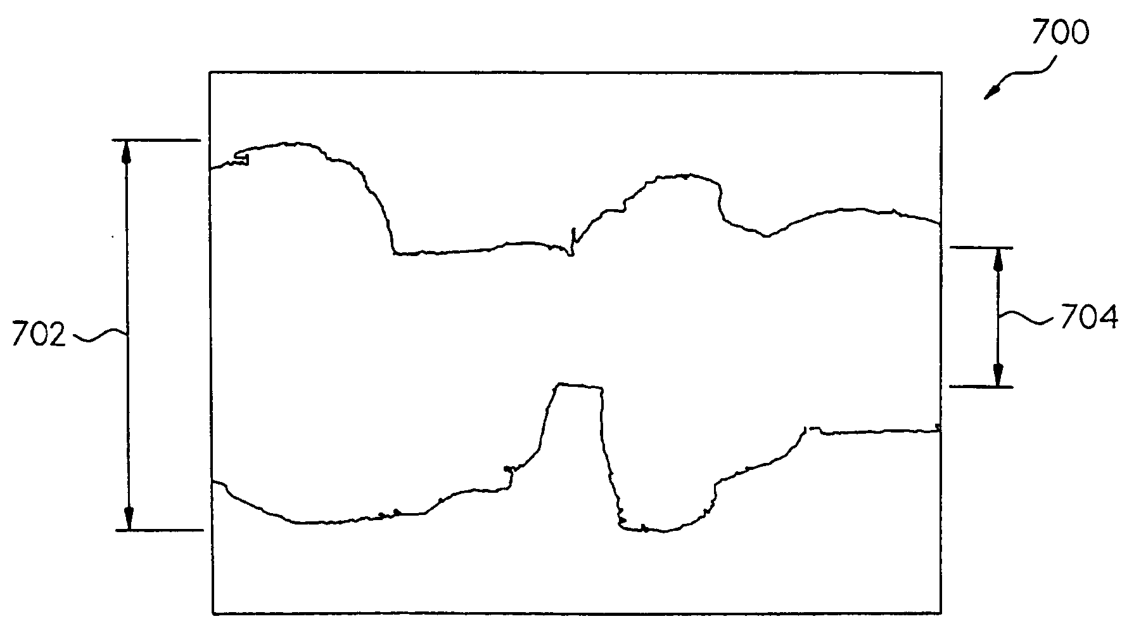


FIG. 7

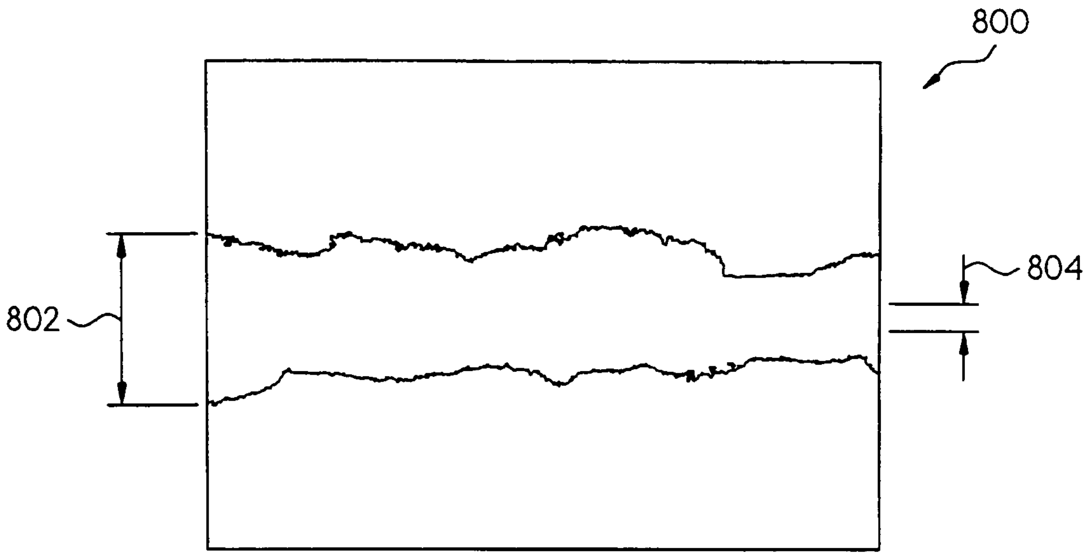
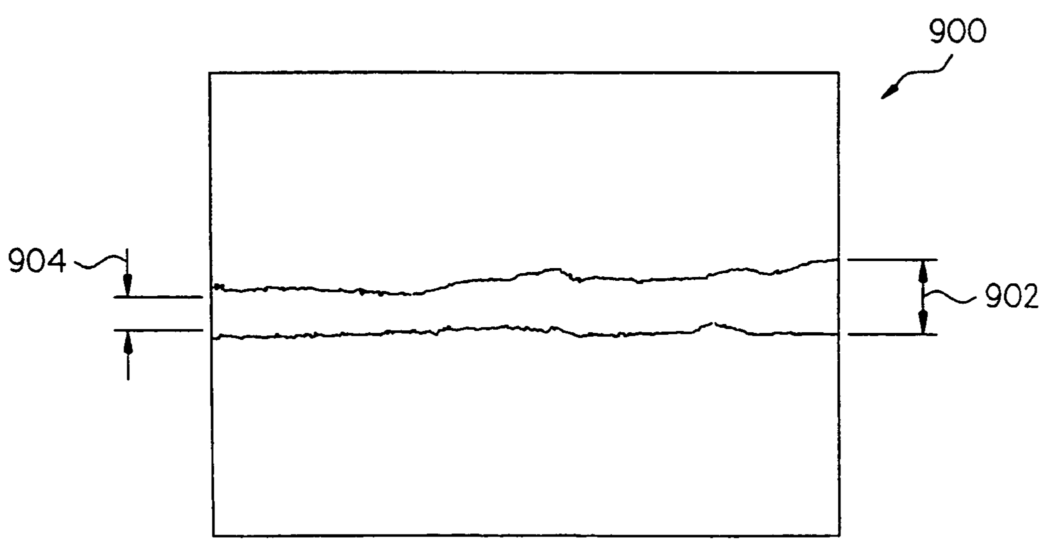


FIG. 8



10 [w] treated

FIG. 9

15 [w] treated

FIG. 10

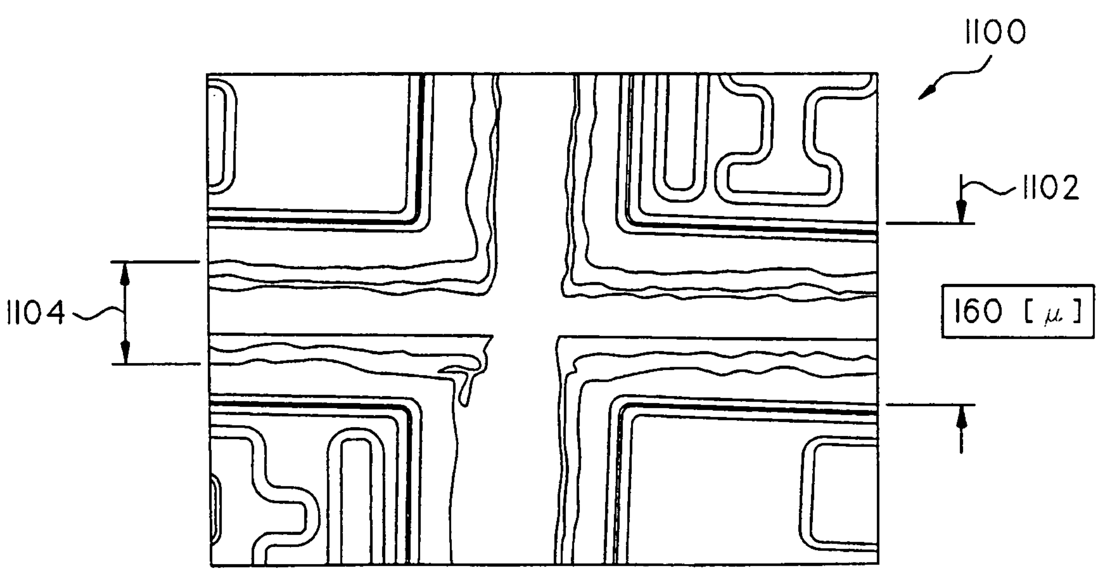


FIG. 11

INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 00/15530

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H01L21/784

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 H01L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 0 818 818 A (NIPPON ELECTRIC CO) 14 January 1998 (1998-01-14) column 1, line 49 -column 2, line 1 column 2, line 53 - line 56 column 3, line 20 - line 57 ---	1-4,11, 14,15
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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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18 September 2000	27/09/2000

Name and mailing address of the ISA	Authorized officer
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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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